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TweetAurora.com –
Citizen Scientists Experiencing the Extremes of Space Weather

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Abstract

On the evening of October 24, 2011 a geomagnetic storm raged across Europe and the United States. Aurora was visible as far south as Alabama in the US, and social media networks helped transmit the visibility of the lights. The purpose of this proposal is a proof of concept demonstration for collecting, analyzing, and interpreting data on the dynamics and evolution of auroral events via real-time social media, which acts as a sensor array distributed in both time and space. We will validate the efficacy of this observational framework by comparison to measurements and predictions of geomagnetic activity as provided by the NOAA Space Weather Prediction Center. We hypothesize that time-domain volunteered information (VI) from the Twitter social network can be derived with sufficient integrity to track events as they unfold and possibly predict events and their impending severity. By comparing the derived information with other space-based and ground-based measurements of an event, we further hypothesize that the derived information can be used as a complementary data source for scientific research of the event.

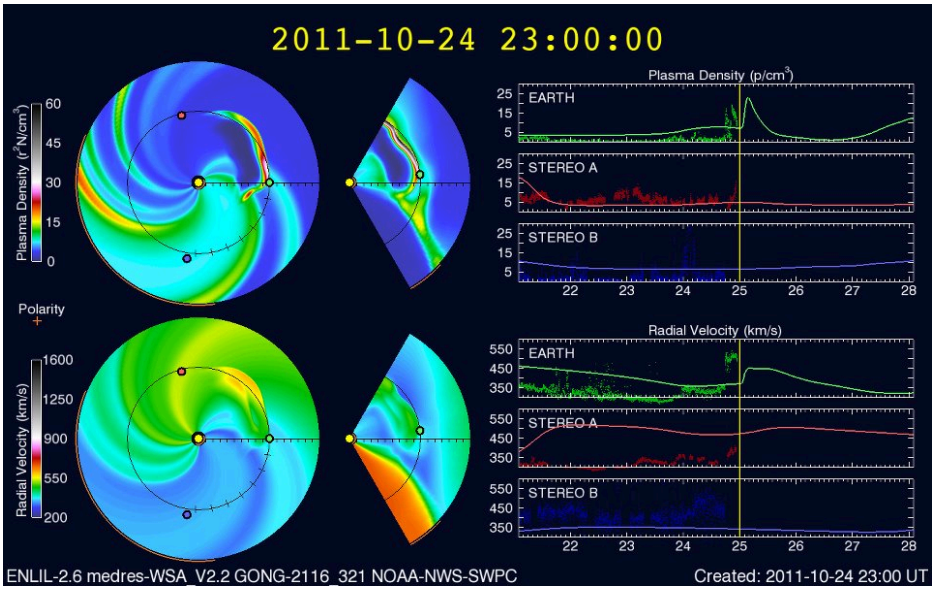
Research Goals

Over the next year, the current 11 year solar cycle will reach its maximum and an unprecedented opportunity to engage the public in social media based citizen science will exist. The goal of this project is a proof of concept demonstration for collecting, analyzing, and interpreting data on the dynamics and evolution of auroral events via real-time social media, which acts as a sensor array distributed in both time and space. We will validate the efficacy of this observational framework by comparison to measurements and predictions of geomagnetic activity as provided by the NOAA Space Weather Prediction Center (www.spaceweather.gov). We hypothesize that time-domain volunteered information (VI) from the Twitter social network can be derived with sufficient integrity to track events as they unfold and possibly predict events and their impending severity. By comparing the derived information with other space-based and ground-based measurements of an event, we further hypothesize that the derived information can be used as a complementary data source for scientific research of the event.

Background & Significance

Los Alamos has a rich history and deep capability for characterizing the Earth's space environment. Nevertheless, the space environment around Earth and the drivers of geomagnetic activity remain a substantial challenge due to the enormous spatial scale of the system and complexity of mass and energy flow. Space weather observations are simply not plentiful enough to accurately forecast the 93 million miles of interplanetary plasma between the Sun and the Earth and its multitude of effects on the Earth's space environment. The end result of these processes, the visible aurora, is especially difficult to predict to the general public. A network of aurora observers on the ground can be greater than an order of magnitude more accurate in time and space than our best forecasting of effects on the Earth. This advance will be enabled by ubiquitous connectivity to each other via social media on the Internet available 24/7 on our computers and mobile devices. We believe that now-casting auroral visibility could be dramatically improved, reducing spatial baselines from hundreds of km to several km with latency reduced from hours to seconds. The Twitter social media network is truly time-domain in a very unique way; each Tweet forms part of a real-time feed, and each communication is time-stamped and can include geolocation information as well. Developing that network to reach the public and engage them through social media into a real-time forecasting effort is one goal of this volunteered geographic information opportunity. The tools are in place and with the recent rise of social media networks over the last 5 years an opportunity for engaging the public as individual observers in real-time exists during the upcoming 11 year solar maximum as never before.

The timing of the October 2011 geomagnetic storm was ideal for auroral observation by North Americans on the Eastern seaboard and mid-West. Solar observations showed that the coronal mass ejection (CME) emitted from the Sun that drove this storm was not particularly energetic and the solar wind conditions that typically drive large geomagnetic disturbances were not present. However, the magnetic field configuration of the solar wind was conducive to highly geo-effective energy storage in the Earth's magnetosphere. This energy was stored for several hours as a large geomagnetic storm began and energy was released in the form of precipitation into the atmosphere. In addition this storm featured rare red aurora at extremely high altitudes resulting in far greater than normal visibility to humans (~800 km further South than more typical auroral emissions).



NOAA NWS Space Weather Prediction Center

The Coronal Mass Ejection observed Saturday morning arrived earlier today (Monday EDT and GMT), about 8 hours earlier than model guidance suggested. Significant space weather is not expected. Early phases of the event have reached the G1 level (http://go.usa.gov/9oi), but that should be close to the peak seen in this event. At the G1 level, weak power grid fluctuations and minor impacts on satellite operations are possible. Any power grid fluctuations are handled by the power companies and will not be visible to end customers. As for Aurora, keep an eye on the SWPC test forecast product called Ovation (http://go.usa.gov/XrR), but in general, you need to be far north in a place where you are used to seeing the aurora to have a chance of seeing anything at these levels.

As always, keep your browser tuned to www.spaceweather.gov

Figure 1: Space weather model prediction and inaccurate NWS forecast for the storm on October 24, 2011.

This storm was an unexplained anomaly in several ways. First, the solar observations of the emission of the CME from the Sun mis-timed its arrival at Earth by 8 hours and, additionally, predicted a much weaker geomagnetic storm than was observed. This model prediction is shown in Figure 1. This inaccuracy is actually fairly typical and reflects the current state-of-the-art in space weather forecasting. Secondly, the mechanisms that caused this particular storm to differ from others and produce the more widely visible red emissions are not fully understood scientifically and thus not included in any forecasting of which we are aware. This project can help document observations and now-cast dynamic auroral behavior by functioning as a distributed ground-based VI data array.

R&D Approach

We will establish a real-time website named *TweetAurora.com* that geographically displays filtered Twitter Tweets related to observing the Northern Lights. Processed Tweet data-to-information displayed could include the user's Tweet, location, observation time, and any auroral characteristics observed (e.g. emission color or location in the sky). The website would display pertinent scientific background and satellite and ground-based observations for further public inquiry. The website's users would register so that they can be contacted in the event of future auroral sightings in their locale. Twitter itself could be used to feedback the real-time observations to the original observers or followers with optimized queuing protocols. The end user will benefit from pin-point forecasts of space weather activity essentially mapping out the auroral oval in real time. This product would increase public appreciation and literacy of a scientific phenomenon and generate scientifically valuable data as well.

The recent storm, due to the excellent timing and widespread visibility over clear skies in heavily populated areas was later covered by more than 500 traditional and online news outlets ranging from international, national, regional, and blog level coverage. Figure 2 shows Google News tracking of this story. Our project's tool can be used and therefore publicized by the media; while

this will be an excellent public demonstration of Lab science and technology, we will also correlate media coverage and Twitter activity to track the influence of public media on the volume and value of data as a VI observational array.

Methods

The solar cycle will produce several more events of this magnitude or stronger. The recent event only reached a planetary K index (Kp) of 7 on the scale of 9. The public interest is clearly high and the social media networks are up to the scale and ripe for use for this higher purpose. As further evidence of the latter point, the recent East coast earthquake produced a large volume of tweets that were mapped in a similar manner to our intent (for more details, see *http://blog.socialflow.com/post/7120244132/all-shook-up-mapping-earthquake-news-on-twitter-from-virginia-to-maine*).

Utilizing this novel technology and partnering with its progenitors, Gilad Lotan, Vice President of Research and Development at SocialFlow has produced for us a similar post-event analysis for the storm on October 24th, 2011. In real time, Tweets exceeded 1 per second during the event. 9000 auroral Tweets were analyzed of which the vast majority were actually about the Northern Lights and about half were sightings. Our website will display these observations in real-time effectively mapping out the current visible extent of the auroral oval (see example in Figure 3). For each registered website user, we can then provide a customized nowcast of auroral visibility based on their location relative to the real-time VI auroral oval. We aim to demonstrate the first use of social media to not just observe scientific phenomena but to make actionable forecasts. Importantly, we are emerging from the most persistent and quiet solar minimum of record, indicating dynamics of the Sun not previous-

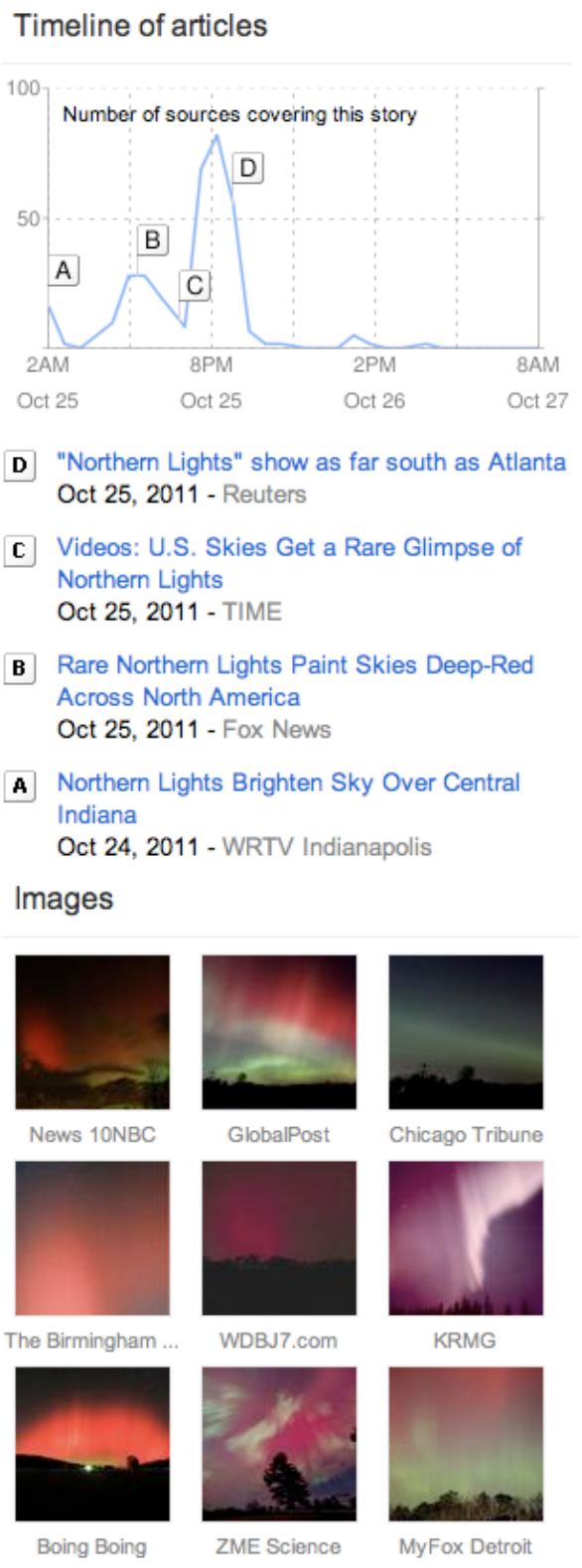


Figure 2: Top, a partial list of news stories covering the aurora on October 24. Bottom, a Google image collage of news stories covering the aurora observed by citizen scientists on October 24th.

ly observed. The solar cycle rise toward solar maximum is likely to be the most-studied on record, and we anticipate that this will be a rich, unique, and publicly engaging data set on the Sun's impact on the Earth's space environment.

Expected results

The expected results for this project include a completed and easy-to-use website to engage the public, serve as a media tool, and a basis for VI data collection. This website will include a continuously updating auroral map based on real-time analysis of Twitter Tweets for auroral sightings. It will also include registration and automated response mechanisms for both recording observations and receiving forecasted information. Additional expected results include publishing our successful proof-of-concept and responding to media requests.

Schedule

We expect to release a beta version of the website within 2 months. A final tested version including geographic forecasting will be completed within 4 months. At that time we will publicize our capability within scientific and social media communities and begin to gather registered users and interest. The exact occurrence of large geomagnetic storms is unpredictable but several should occur over the next year and we will be ready to respond. This project should complete nominally within FY12 assuming that a sufficiently large event occurs.

Mission Relevance & Program Development Plan

This is a time sensitive idea and we have an immediate need to establish our interests and promote the idea. We will partner with the Twitter analytics capabilities of SocialFlow. Ultimately communicating the beauty of the aurora to the general public is an achievable goal with far-reaching consequences for addressing the 21st century's gaps in science education and literacy. We anticipate submitting this idea for E/PO funding to the NASA Radiation Belt Storm Probes program (or a related organization) to develop an operational system based on our proof-of-principle demonstration.

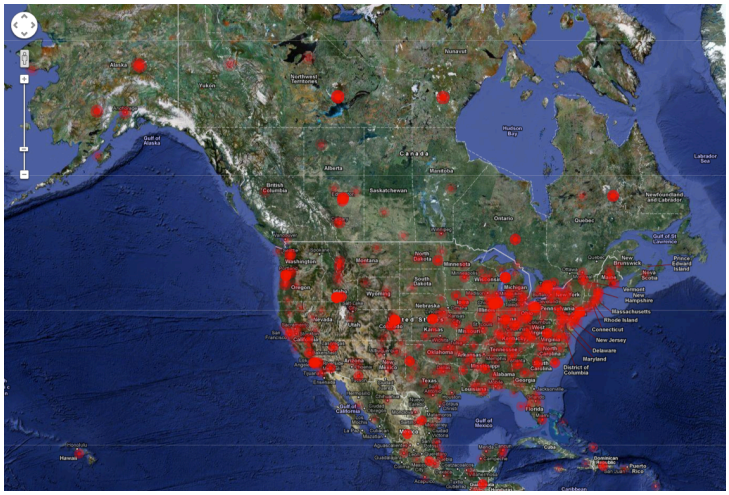


Figure 4: A sample of mapped auroral sighting Tweets from the geomagnetic storm on October 24th, 2011. This storm was fortuitously timed to maximize viewing for mid-latitudes of the East Coast, mid-West, and the Southern regions of the US. Each circle represents a single Tweet with darker circles representing more reported observations. Locations are based on what users placed in their public profiles (courtesy of Social Flow, *www.socialflow.com*).

Longer term, we also anticipate significant opportunities to spin-off this idea into other information science and applied complexity opportunities. From this perspective, understanding and exploiting the time domain volunteered information leads to an end objective of event prediction and characterization. What is the information content needed for prediction and what is the process by which the data is processed into information? What complementary information can be derived by a VI observational array that cannot be derived from traditional sci-

entific instruments? What are the underlying dynamics of a VI observational array (time, spatial scale dependence), including the influence of public media on data volume and integrity? We hope to answer these questions and enable high time resolution of dynamic phenomena as they evolve. This system is ideally and uniquely configured for early warning of events and tracking the evolution of events on timescales down to minutes or seconds. No other social media network or current auroral forecasting technology can provide this temporal and spatial resolution and so this concept will serve as a state-of-the-art demonstration of the powerful application of volunteered geographic information systems.